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Robust Mouse Control based on Dynamic Template Matching of Hand Gestures

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Abstract
This paper introduces the application of the Template Matching algorithm in recognition dynamic hand gestures. Images undergo thresholding to convert each pixel of image into binary which will eventually be filtered to reduce the noise present. To make consistent and precise detection, this image can still be improved by enhancing the edge of the hand, which serves as the initial input for the process of template matching. The saved templates serve as the basis for comparison in Template Matching algorithm. The processed sequence of images will be compared to the templates saved in the database. When the current templates have significant relation or no significant relation to the saved database, the result will turn to the recognition of the mouse function. Hence, the mouse function will be executed.

Keywords: *template matching, dynamic hand gesture, virtual mouse*

Nomenclature

PCA	Principal Component Analysis
RGB	Red, Green and Blue
YCBCR	Luminance; Chroma Blue; Chroma Red
3D	Three-dimensional

1. Introduction
The evolution of computer mouse has become a vigorous trend as technology develops rapidly. Yet, there have been many transformations of a computer mouse since the start of its invention, from a trackball to an optical mouse. Today's generation has become more involved in creating devices that can replace mechanically operated technologies. One of the technologies that substituted the traditional computer mouse is called virtual mouse. This technology enables the user to navigate the window and execute functions of a mouse by only executing actions like static hand gestures.

A research study entitled "Gesture Recognition Based Mouse Events" [13] that achieved 87.5% rate of recognition, involves the use of YCbCr color model. In this method, the dependency on light intensity has been eliminated. To track the gesture positions, selection of the RGB colours is used to perform mouse functions. Another paper entitled "Simulation of Real-time Hand Gesture Recognition for Physically Impaired" [9] uses Principal Component Analysis (PCA) by combining hand gesture recognition based on centroids with real-time 3D hand tracking, which achieved a recognition rate of 87.75%. A recent research for virtual mouse using static hand gesture recognition entitled "Cursor Control Using Hand Gestures and a Webcam" [10] that received a recognition rate of 58.8%%. It used convexity defects of hand contour and analysed the fingertips and the angle of the fingers in order to perform the mouse functions.

Based on the previous studies that used static gesture recognition, the tremor of the hand has become more noticeable when hanged in the air. Thus, due to the low precision detection of gesture caused by the instability of the hand, misdetection and inaccuracy of recognition had been the results.

The authors intend to provide a system that can recognize the dynamic hand gestures as mouse control. It integrates the use of dynamic hand gestures to eliminate the effect of tremor of the hand in recognizing the gesture. Embedded in the system are the templates saved in the database. These frames are composed of pictures which are captured from the starting position of the hand until the last position of the hand while performing a certain mouse function, served as the pilot copy in the database. The system integrates the method of template matching to increase the accuracy of the hand gesture recognition. As the camera detects a hand gesture, the captured input data will be processed through thresholding.

Reduction of noise is also necessary by implementing image filtering and edge sharpening for the enhancement of the edges of the hand. Template matching of the saved templates and the current detected templates is the next process of the system. From the frames of the templates, the current template will be matched to the saved templates. If there is relation in the matching process, the gesture would be recognized. Thus, the mouse control with respect to the recognized gesture is performed.

The remained of the paper is organized as follows: Section (2) discusses the theory about Template Matching algorithm, how it works and how it is applied in the system to recognize dynamic hand gesture; Section (3) presents the results and discussion; and Section (4) presents the conclusion where the summary of the contribution of this work and identify areas for further work is presented.

2. Theory

The system for recognizing the dynamic hand gesture is equipped with the use of computer with 2.3 GHz 8GB RAM, administering Windows 7. This is made possible through the use of Microsoft Visual Studio 2012, which has embedded Aforge and Accord framework for C# .NET language, with MS Visual Studio form environment. The assessment of the result depends on the performance of the system. The set up for the distance of the hand and the camera is approximately 1 meter, depending on the external interferences.

A. Recognizing dynamic hand gesture using Template Matching algorithm for controlling a virtual mouse

Figure 1 illustrates how the system works step by step. It starts from how the camera captures the movement until the recognition of the dynamic hand gesture. After the camera detects the gesture, the captured input data would be processed through the method of segmentation to identify the correct contour.

For the reduction of noise, filtering is necessary to have a clear image of the hand through smoothening, sharpening and edge enhancement. Once the data is easily distinguished, the process for gesture recognition proceeds. Template matching of the saved templates and the current detected templates is the next process of the system.

Subsequently, this study involves the use of dynamic hand gestures; the data should include sequence of frames according to the posture of the hand. The saved templates would be used as the reference for comparison to the acquired data. This system integrated a program for mouse events. When there is correct matching, the system will automatically perform the mouse function.

From the pre-processing segment of the system, the user's way of moving his or her hand allows the system to either easily recognized the gesture or does not recognize the gesture performed. The detection of the system depends on how the environment affects the capturing of the hand, and how the user executes certain mouse function which also determines that the hand of the user must be of the same orientation as the saved templates. Moreover, this paper involves the application of the Template Matching algorithm in recognizing the dynamic hand gestures to make this system be more accurate in recognizing moving gestures. For the result of the system, the current templates have significant relation or no significant relation to the saved database.

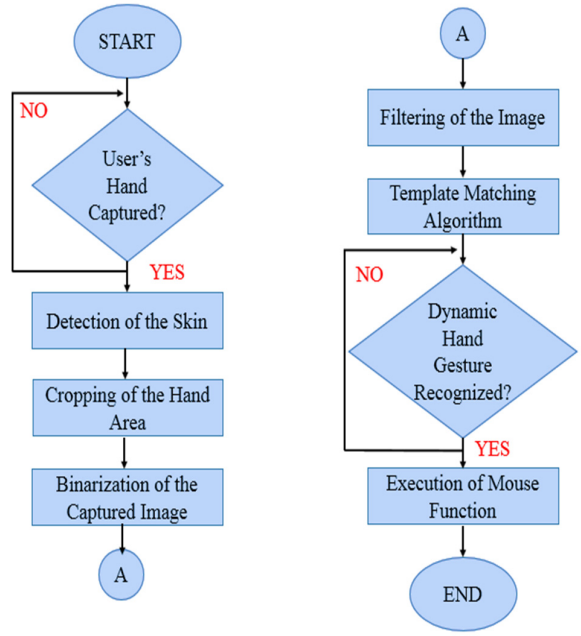


Figure 1. Conceptual Framework

Figure 2. Hand Detection for HSV Color Model

Hand Detection: This includes processes of acquiring data from the Template Matching algorithm. The raw data of the system are the frames or postures of the hand while performing a certain mouse function. The skin detection method is used to determine the hand area. The R, G and B pixels are used to find the skin regions that includes a wide range of colors such as red, pink, brown and orange. Training samples of skin region is done by saving a sample color. Once the hand is identified through skin detection, image segmentation is the next process to be done. It is applied to separate the arm region from the hand region. When the threshold process takes place, which involves replacing each pixel of an image into black pixel where the image intensity is lower than some set constant or a white pixel if it is higher than that set constant, the next processes are the noise reduction and sharpening of the hand to enhance the edges.

Template Matching Algorithm: This process involves comparing and classifying the acquired data of the hand gesture to the saved templates. Since Template Matching is the involved process in performing the dynamic hand gesture, each gesture has its respective set of frames that are dependent on how the gesture is being done.

The concept of Template Matching is to provide a reference image and an image to be compared to the saved templates during the Template Matching process. The designated dynamic hand gesture will have certain time for training and saving the templates. The saved templates after the training will have 4 images that comprise the template.

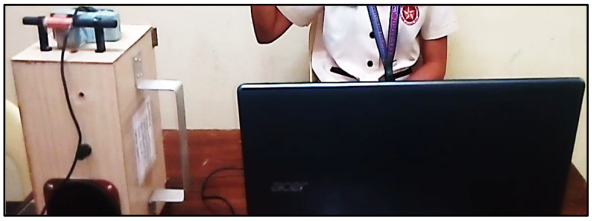


Figure 3. Hardware of the System

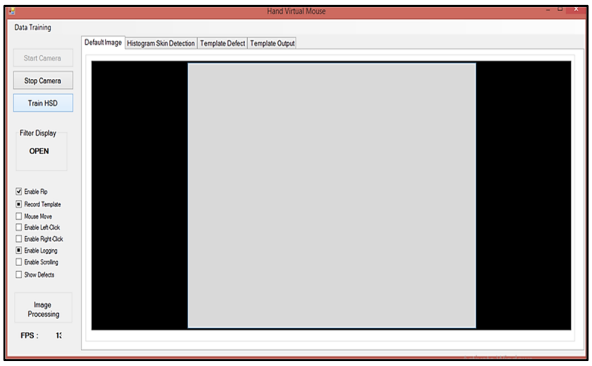


Figure 4. Software Applied in the System

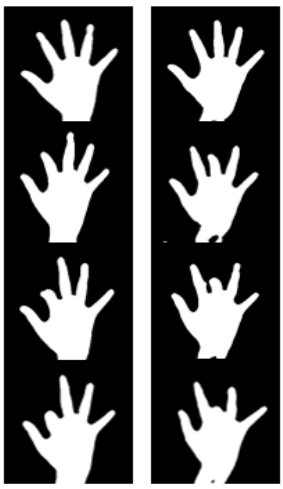


Figure 5. Template for Clicking Functions: Left click (left) and Right Click (right)

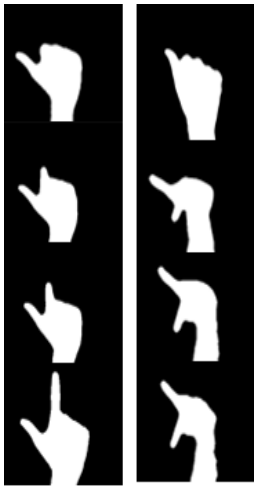


Figure 6. Template for Scroll Functions: Scroll-up (left) and Scroll-down (right)

The user will execute a dynamic hand gesture that has equivalent mouse function. The data will start from the frames or posture of the hand from the beginning up to the final position of the hand. The saved frames for each template will be compared to the current set of images. Correct recognition of the hand can only be possible if the pre-processes for hand detection are achieved correctly. When the templates to be compared are turned into binary (white and black), the process for template matching is also initialized. The user should conduct an experiment in which the system would compare the current templates of each dynamic hand gesture to the saved templates.

Gesture Recognition: To compare current templates to the saved templates, posture and positioning of the fingers should be properly observed. Left click function is executed by bending the index finger, just like how a mechanical mouse is used. For right click, the middle finger should be slightly bent also. For the scroll up and down, the templates are illustrated. In drag and drop functions, index finger is also used.

B. *Evaluating the system's performance in terms of accuracy and identifying the significant improvement of the current study in comparison to the previous studies*

This paper focuses on how to increase the accuracy rate of gesture recognition for mouse control and its significant improvement from the previous study. The scheme for assessing the system's performance is that the accuracy of the hand based on the actual dynamic gesture and image template is checked by performing the mouse functions so that it can be proved that the instability of the hand will not affect the performance in terms of accuracy of the mouse functions since the gesture is based on dynamic movements. The method for evaluating the accuracy is to perform 30 trials for each mouse function.

To compute for the accuracy rate of the system, recognition rate formula is involved. Number of recognized gestures will be provided from the experiment conducted by the proponents. To know the error rate of the system, number of unrecognized gestures over the total number of trials is the formula to be used.

$$Recognition\ Rate = \frac{Number\ of\ Recognized\ Gestures}{Number\ of\ Trials\ for\ Each\ Mouse\ Function}\ x\ 100 \quad (1)$$

$$Error\ Rate = \frac{Number\ of\ Unrecognized\ Gestures}{Number\ of\ Trials\ for\ Each\ Mouse\ Function}\ x\ 100 \quad (2)$$

This study provides a system that can recognize a certain dynamic hand gesture that has corresponding mouse function. It involves six mouse functions such as left click, right click, double click, scroll up, scroll down and drag and drop. The accuracy rate is the implicated parameter which needs to be improved by the current study. The result of the current study will be compared to the data of the previous study provided below and it will be used to identify the significant improvement of the current study from the previous studies.

Table 1. Result from the Study Entitled "Gesture Recognition Based Mouse Events"

Mouse Functions	Detection Rate
Right Click	92%
Left Click	87%
Double Click	87%
Drag and Drop	84%

Table 2. Result from the Study Entitled "Simulation of Real-time Hand Gesture Recognition for Physically Impaired"

Mouse Functions	Detection Rate
Right Click	88%
Left Click	91%
Scroll Down	87%
Scroll Up	85%

Table 3. Result from the Study Entitled "Cursor Control System Using Hand Gesture Recognition"

Mouse Functions	Basis
Right Click	13/30
Left Click	11/30
Double Click	16/30
Scroll Down	3/30
Scroll Up	19/30

3. Results and Discussion

The study aims to provide a system that can achieve a high accuracy rate in terms of recognizing the dynamic hand gesture for each mouse movement. The authors conducted the gathering of data by allowing 30 trials for each mouse function to be executed by the user.

Table 4. Result of the Study

Mouse Functions	Recognized	Missed
Left Click	30/30	0/30
Right Click	28/30	2/30
Double Click	25/30	5/30
Scroll Up	30/30	0/30
Scroll Down	30/30	0/30
Drag and Drop	28/30	2/30

Some of the samples exhibiting recognition errors or misclassified errors are shown in Table 4. In the experiment that was conducted by the proponents, the mismatched mouse functions are as follows: right click, double click, and drag and drop.

Table 5. Mismatched and Unrecognized Gestures

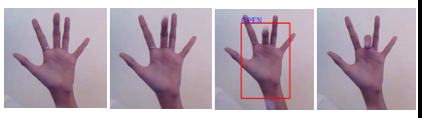
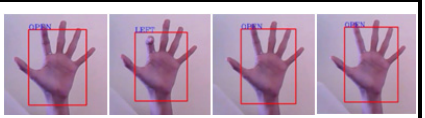
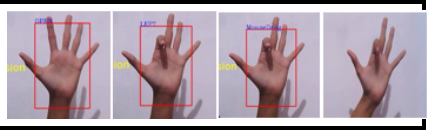
Right Click	
Saved Template	
Mismatched Actual Performance	
Double Click	
Unrecognized Actual Gesture	
Drag and Drop	
Unrecognized Actual Gesture	

Table 5 indicates the mismatched templates and unrecognized gestures from the gathered data. Due to the variation of finger positions in the frames extracted from the real-time video, it lead to erroneous detection of the hand features that caused the system to misinterpret the gesture being performed by the user. The last position of the gesture performed is incorrectly recognized shown in Table 5, since double click function is set as two consecutive left click function like a mechanical mouse, the user is likely to perform the double click function immediately without a pause that lead to recognition of incorrect gestures. The function drag and drop is not properly recognized due to the improper orientation of the hand in the last position of the frames extracted from the real-time video.

Table 6. Accuracy Rate and Error Rate of the System

Mouse Functions	Accuracy Rate	Error Rate
Left Click	100%	0%
Right Click	93.3333%	6.6667%
Double Click	83.3333%	16.6667%
Scroll Up	100%	0%
Scroll Down	100%	0%
Drag and Drop	93.3333%	6.6667%

Table 6 indicates the accuracy rate and error rate of the system's performance. The accuracy rate is computed using the formula for the recognition rate. Recognition rate is just the ratio of success recognitions to the total number of trials. The system's performance in terms of accuracy for the left click, scroll up and scroll down is 100%. There is 93.3333% for the mouse functions right click, and drag-and-drop. For the double click function, there is 83.3333% of recognition rate.

The tables below show the significant improvement of the current study from the previous studies.

Table 7. Comparison of Recognition Rate of the Current Study from the Study Entitled "Gesture Recognition Based Mouse Events"

Mouse Functions	Current Study	Previous Study
Left Click	100%	87%
Right Click	93.3333%	92%
Double Click	83.3333%	87%
Drag and Drop	93.3333%	84%
Overall Recognition Rate	92.5%	87.5%

Table 8. Comparison of Recognition Rate of the Current Study from the Study Entitled "Simulation of Real-time Hand Gesture Recognition for Physically Impaired"

Mouse Functions	Current Study	Previous Study
Left Click	100%	91%
Right Click	93.3333%	88%
Scroll Up	100%	85%
Scroll Down	100%	87%
Overall Recognition Rate	98.3333%	87.75%

Table 9. Comparison of Recognition Rate of the Current Study from the Study Entitled "Cursor Control System using Hand Gesture Recognition"

Mouse Functions	Current Study	Previous Study
Left Click	100%	63%
Right Click	93.3333%	57%
Double Click	83.3333%	47%
Scroll Up	100%	37%
Scroll Down	100%	90%
Overall Recognition Rate	95.33332%	58.8%

In identifying the system's performance in terms of its accuracy, the authors executed 30 trials for each mouse function which is based on the reference journal. The current system is able to identify six (6) mouse functions, while the previous system has 5 mouse functions. This study has recognition rate of 83 to 100 percent for each mouse function. This numerical value signifies that there is only low number of missed recognition for each mouse function with error rate of 5.0002%.

The authors assess the result of the experiments by observing the possible reasons of the missed recognition.

From the gathered data, it can be seen that there are several reasons for the misclassification of the gestures. The authors evaluate that some misclassified gestures are caused by disorientation because of the tilting or slanting of the user's hand while executing a function (drag and drop). It is also show that when the gesture is not performed well from the start of the execution, misclassification of the hand gesture occurs which affects the recognition of the system. This happens when the system (camera) is not able to determine that the user already moved her finger, in case of the right click function.

This study aims to compare the result with previous studies. As to compare the results from the previous study, the overall system's performance with regards to accuracy is computed based on the five mouse functions. The previous study achieved a rate of recognition of about 58.8% while the current study has overall recognition rate of 95.33332%.

The authors also compare the result of the experiment from other two papers. The results of the past studies are 87.75% and 87.5%. The result of the current study implies that there is significant improvement in terms of accuracy of the system.

4. Conclusion

Recognition of the dynamic hand gesture is carried upon the implementation of Template Matching in executing mouse functions. The designated dynamic hand gestures for the mouse functions are unique, so that it will not cause confusion to the system. The saved template is used as a basis for comparing the actual template executed by the user and the existing template.

The authors find that hand detection process of the system highly affects the recognition process of the dynamic hand gesture because the pre-processes of the system should be completed properly to make the actual templates have less noise and be ready for recognition process. This means that when the detection is not properly working, process of matching will be affected. This detection is affected by the lighting condition of the place where it is performed. The proponents are able to arrive with a system that will manage proper recognition of dynamic gestures that are the same in controlling a commercialized mouse.

The authors conclude that the current system surpassed the system's performance of the previous studies. This study also proves that the problem of inaccuracy due to tremor of the hand has been eliminated by integrating Template Matching algorithm in dynamic hand gestures.

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